PB82-118654

Analysis of Commercial Cylinder Gases of Nitric Oxide, Sulfur Dioxide, and Carbon Monoxide at Source Concentrations: Results of Audit 5

Research Triangle Inst.
Research Triangle Park, NC

Prepared for

Environmental Monitoring Systems Lab.
Research Triangle Park, NC

Oct 81

U.S. Department of Commerce
National Technical Information Service
NTIS.

PB82-118654

EPA-600/4-81-080
October 1981

FINAL REPORT

ANALYSIS OF COMMERCIAL CYLINDER GASES OF NITRIC OXIDE, SULFUR DIOXIDE, AND CARBON MONOXIDE AT SOURCE CONCENTRATIONS

Results of Audit 5

by

C. E. Decker
W. C. Eaton
R. C. Shores
C. V. Wall

Prepared for

Quality Assurance Division
Environmental Monitoring Systems Laboratory
Environmental Research Center
Environmental Protection Agency
Research Triangle Park, North Carolina 27711

EPA Contract No. 68-02-3431
EPA Project Officer: D. J. von Lehmden

June 1981

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA 22161

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/4-81-080	2. ORD Report
3. RECIPIENT'S ACCESSION NO. PB82 118654	
4. TITLE AND SUBTITLE ANALYSIS OF COMMERCIAL CYLINDER GASES OF NO, SO_2 and CO AT SOURCE CONCENTRATIONS: RESULTS OF AUDIT 5	5. REPORT DATE October 1981 6. ON CODE U289061
7. AUTHOR(S) C.E. Decker, W.C. Eaton, R.C. Shores and C.V. Wall, Research Triangle Institute, Research Triangle Park, North Carolina	8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Research Triangle Institute Research Triangle Park, North Carolina 27709	10. PROGRAM ELEMENT NO. GAP - 1AAF60E10J 11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS U.S. Environmental Protection Agency Office of Research and Development Environmental Monitoring Systems Laboratory (MD-75) Research Triangle Park, North Carolina 27711	13. TYPE OF REPORT AND PERIOD COVERED 14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

Manufacturers of commercial cylinder gases supply standards with a certified analysis and a statement of accuracy. Generally, the level of accuracy is specified as a percentage of the component value. To ascertain the accuracy of analyses of commercially available cylinder gases, the Environmental Protection Agency (EPA) has initiated a national performance audit program of commercial gas manufacturers. Audit 1 was performed in June 1978, Audit 2 was performed in January 1979, Audit 3 was performed in September 1979, and Audit 4 was performed in April 1980. A summary of these results is included in this report.

The purpose of Audit 5 was to analyze the concentration of cylinder gases purchased from a representative sample of manufacturers and determine the accuracy of the manufacturers' certified concentrations. Audit 5 included cylinders of sulfur dioxide (SO_2) at 90 and 500 ppm, nitric oxide (NO) at 50 and 300 ppm, and carbon monoxide (CO) at 50 and 500 ppm obtained from 14 different manufacturers. Audit 5 was performed from March through June 1981. Audit 5 results are summarized in this report.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Cylinder gases, accuracy, certified analysis, sulfur dioxide, nitric oxide, and carbon monoxide		

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES
RELEASE TO PUBLIC	UNCLASSIFIED	23
	20. SECURITY CLASS *(This page)* UNCLASSIFIED	22. PRICE

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

CONTENTS

Section		Page
1.0	SUMMARY	1
2.0	INTRODUCTION	4
3.0	CYLINDER GAS ANALYSIS AND TRACEABILITY PROCEDURE	8
	3.1 Analysis of NO Cylinders	8
	3.2 Analysis of SO_2 Cylinders	9
	3.3 Analysis of CO Cylinders	10
	3.4 EPA Quality Assurance Program	11
4.0	RESULTS OF CYLINDER GAS ANALYSES	13
5.0	SUMMARY OF RESULTS OF AUDITS 1 through 5	17

SECTION 1

SUMMARY

Manufacturers of commercial cylinder gases supply standards with a certified analysis and a statement of accuracy. Generally, the level of accuracy is specified as a percentage of the component value. To ascertain the accuracy of analyses of commercially available cylinder gases, the Environmental Protection Agency (EPA) has initiated a national performance audit program of commercial gas manufacturers. Audit 1 was performed in June 1978, Audit 2 was performed in January 1979, Audit 3 was performed in September 1979, and Audit 4 was performed in April 1980. Audits 1 and 2 included cylinders of sulfur dioxide and nitric oxide at source concentrations. Results of these audits were reported in "Analysis of Commercial Cylinder Gases of Nitric Oxide and Sulfur Dioxide at Source Concentrations - Results of Audits 1 and 2."* Audit 3 included cylinders of sulfur dioxide, nitric oxide, and carbon monoxide, and a reanalysis of cylinder gases included in Audit 2. Results of Audit 3 are included in "Analysis of Commercial Cylinder Gases of Nitric Oxide, Sulfur Dioxide, and Carbon Monoxide - Results of Audit 3."* Audit 4 included cylinders of sulfur dioxide, nitric oxide, and carbon monoxide, and a reanalysis of cylinder gases included in Audit 3. Results of Audit 4 are included in "Analysis of Commercial Cylinder Gases of Nitric Oxide, Sulfur Dioxide, and Carbon Monoxide - Results of Audit 4."* A summary of these results is also included in Tables 8 through 10 of this report.

The purpose of Audit 5 was to analyze the concentration of cylinder gases purchased from a representative sample of manufacturers and determine the accuracy of the manufacturers' certified concentrations. A reanalysis of the cylinder gases analyzed in Audit 4 was not performed during Audit 5, since stability of these gases had been demonstrated in Audits 2 through 4.

---

*Report available from the Quality Assurance Division, Environmental Monitoring Systems Laboratory, Environmental Protection Agency, Research Triangle Park, North Carolina 27711.

Audit 5 included cylinders of sulfur dioxide (SO_2) at 90 and 500 ppm, nitric oxide (NO) at 50 and 300 ppm, and carbon monoxide (CO) at 50 and 500 ppm obtained from 14 different manufacturers. Audit 5 was performed from March through June 1981. The procedure used by Research Triangle Institute (RTI) to analyze Audit 5 cylinder gases was EPA's "Traceability Protocol for Establishing True Concentrations of Gases Used for Calibration and Audits of Continuous Source Emission Monitors" (Protocol No. 1, June 15, 1978). Audit 5 results are summarized in Table 1.

TABLE 1. SUMMARY OF RESULTS FOR AUDIT 5 OF COMMERCIAL CYLINDER GASES FOR SULFUR DIOXIDE, NITRIC OXIDE, AND CARBON MONOXIDE

Manufacturer	Sulfur Dioxide		Nitric Oxide		Carbon Monoxide	
	Nominal Conc. (ppm)	Percent Accuracy	Nominal Conc. (ppm)	Percent Accuracy	Nominal Conc. (ppm)	Percent Accuracy
AGA Burdox, Inc.	500	6.1	300	-0.7	500	-1.4
	90	9.0	50	-2.9	50	-2.3
Air Monitoring Gas Company	500	*	300	-2.3	500	0.4
	90		50	-6.0	50	8.2
Airco Industrial Gases	500	1.4	300	1.0	500	0.4
	90	2.3	50	-2.8	50	4.0
Air Products & Chemicals, Inc.	500	-4.6	300	-1.0	500	-13.0
	90	-31.7	50	-4.4	50	-15.9
Big Three Industries	500	26.1	300	-4.9	500	-0.6
	90	38.4	50	-6.8	50	0.0
Ideal Gas Products	500	11.9	300	0.4	500	3.1
	90	6.0	50	-1.1	50	0.4
Liquid Carbonic Corp.	500	-3.5	300	-2.0	500	0.6
	90	-0.2	50	1.7	50	0.2
Matheson Gas Products	500	-7.0	300	-0.7	500	-13.5
	90	-9.3	50	-3.0	50	-6.5
MG Scientific Gas Products	500	42.8	300	8.1	500	0.8
	90	112	50	20.0	50	-6.7
North East Cryogenics	500	8.2	300	-0.4	500	3.3
	90	12.1	50	1.6	50	-1.0
Scientific Gas Products, Inc.	500	6.2	300	-1.3	500	1.0
	90	11.8	50	-11.4	50	-16.3
Scott Environmental Tech., Inc.	500	-0.4	300	-0.3	500	0.2
	90	3.2	50	-1.1	50	0.8
Scott-Marrin, Inc.	500	-0.4	300	1.0	500	- 0.6
	90	0.2	50	-1.0	50	0.0
Linde Div. of Union Carbide	500	6.8	300	0.6	500	3.3
	90	-40.5	50**	3.1	50	1.8

*Company does not supply SO_2.
**Nominal 50 ppm ordered but 530 ppm shipped.
Percent accuracy = 100(Manufacturer - RTI)/RTI.

SECTION 2

INTRODUCTION

Manufacturers of commercial cylinder gases supply gas mixtures with a certified analysis and a statement of accuracy. The purpose of this project was to analyze cylinders obtained from a representative sample of gas manufacturers and compare the measured concentrations with the manufacturers' quoted analyses. The gases of interest were mixtures of NO, CO, and SO_2 in nitrogen.

A survey was conducted of manufacturers that routinely provide gas mixtures; these companies are listed in Table 2. Fourteen of the thirty-three companies shown in Table 2 were selected to supply gas cylinders for analysis and are listed in Table 3. The other companies were not included because: (1) they do not supply gases used in environmental studies, or (2) they do not blend and analyze their own gases but merely label another manufacturer's product.

Gas mixtures were obtained through a third party to maintain anonymity. Cylinder gases for Audits 1 through 4 were procured by anonymous third parties located in the eastern part of the United States. In an attempt to evaluate the accuracy of cylinder gases produced by the manufacturers' different production facilities throughout the country, a third party located in the western part of the United States was chosen to procure gases for Audit 5. Table 3 includes a listing of the production facilities for gases procured for Audits 1 through 5. The nominal concentrations ordered were:

(1) 300 ppm NO, balance nitrogen.
(2) 500 ppm SO_2, balance nitrogen.
(3) 500 ppm CO, balance nitrogen.
(4) 50 ppm NO, balance nitrogen.
(5) 90 ppm SO_2, balance nitrogen.
(6) 50 ppm CO, balance nitrogen.

TABLE 2. SURVEY OF CYLINDER GAS MANUFACTURERS

AGA Burdox, Inc.
Air Monitoring Gas Company
Air Products and Chemicals, Incorporated
Airco Industrial Gases
Automotive Environmental Systems, Incorporated
Big Three Industries
Chemetron Industrial Gases
Edmond Scientific Company
Essex Chemical Corporation
Ideal Gas Products
J. T. Baker Chemical Company
J. W. Goodliffe Air Products Company
Liquid Carbonic Corporation
Matheson Gas Products
MG Scientific Gases
National Welders Supply Company, Incorporated
New England Nuclear
Northeast Cryogenics
Nuclear Sources and Services, Incorporated
Ohio Chemical and Manufacturing Company
Pipe Welding Supply Company, Incorporated
PPG Industries, Incorporated
Puritan Compressed Gas Corporation
Scientific Gas Products, Incorporated
Scientific Products, Division of American Hospital Supplies
Scott Environmental Technology, Incorporated
Scott-Marrin, Incorporated
Stauffer Chemical Company
Sulfrian Cryogenics, Incorporated
Supelco, Incorporated
Texas Gulf, Incorporated
Union Carbide Corporation, Linde Division
Virginia Chemical, Incorporated

TABLE 3. CYLINDER GAS MANUFACTURERS INCLUDED IN AUDIT PROGRAM

Manufacturer	Production Facility	
	Audits 1-4	Audit 5
AGA Burdox, Inc.	*	Detroit, MI
Air Monitoring Gas Gas Company	*	Royal Oak, MI
Airco Industrial Gases	Research Triangle Park, NC	Riverton, NJ Port Allen, LA
Air Products and Chemicals, Inc.	Tamaqua, PA	Tamaqua, PA La Porte, TX
Big Three Industries	Houston, TX	Houston, TX
Ideal Gas Products	Edison, NJ	Edison, NJ
Liquid Carbonic Corp.	Baltimore, MD	Pasadena, TX
Matheson Gas Products	Morrow, GA	La Porte, TX
MG Scientific Gases	Somerville, NJ	Somerville, NJ
North East Cryogenics	Newtonville, MA	Newtonville, MA
Scientific Gas Products, Inc.	South Plainfield, NJ	Pasadena, TX Brighton, CO
Scott Environmental Technology, Inc.	Plumsteadville, PA	San Bernardino, CA
Scott-Marrin, Inc.	Riverside, CA	Riverside, CA
Union Carbide Corp., Linde Division	East Chicago, IN	East Chicago, IN Houston, TX

*Company not included in audit survey.

Specifications of the type of analysis or the type of cylinder (steel or aluminum) were not included on the purchase request. To avoid compromising the audit, it was necessary to purchase the cylinder gases with the presumption that they would be used for routine purposes. The only specifications given to the manufacturers were cylinder size, component, nominal concentration levels, and a request for a certified analysis. The request for a certified analysis did not specify that manufacturers should analyze cylinder gases according to EPA's Traceability Protocol No. 1.

SECTION 3

CYLINDER GAS ANALYSIS AND TRACEABILITY PROCEDURE

Cylinders were received and grouped by manufacturer, pollutant species, and concentration. The NO, CO, and SO_2 analyses were performed separately using source emission analyzers. Each commercial cylinder was analyzed three times. Between analyses a National Bureau of Standards-Standard Reference Material (NBS-SRM) or a gas manufacturers precision standard (GMPS) that met the EPA average degradation criterion of less than 1 percent per month was introduced as a control check on the analyzer. All procedures met or exceeded the guidelines set forth in EPA's "Traceability Protocol for Establishing True Concentrations of Gases Used for Calibration and Audits of Continuous Source Emission Monitors" (Protocol No. 1, June 15, 1978). Prior to analysis of the commercial cylinders, RTI was required to participate in an EPA audit for NO, CO, and SO_2.

3.1 ANALYSIS OF NITRIC OXIDE CYLINDERS

A Thermo-Electron Corporation (TECO) chemiluminescent NO-NO_2-NO_x analyzer-Series 10 (S/N 10AR-6795-88) was used to analyze the NO cylinder concentrations. The multipoint calibration procedure specified in EPA's Traceability Protocol No. 1 was used to calibrate the TECO analyzer. Two NBS-SRM NO in N_2 cylinders and zero gas (nitrogen) were used to generate calibration concentrations in the range of 0 to 500 ppm. A multipoint calibration (zero level and five upscale concentrations) was performed prior to each set of analyses. The multipoint calibration was accomplished by dilution of the highest NBS-SRM (approximately 2800 ppm) with zero gas (nitrogen) using a dilution system. At the conclusion of the multipoint calibration, a check of the calibration curve was performed using the lower NBS-SRM without

dilution. The response of the instrument based on the original calibration curve (dilution of higher NBS-SRM) was compared to the response to the true concentration of the lower NBS-SRM. If the difference between the apparent concentration (based on dilution of higher NBS-SRM) was less than 3 percent of the concentration of the lower NBS-SRM, then the analyses of audit cylinders provided by EPA could begin. If not, the multipoint calibration was repeated. Agreement to within ±3 percent between the EPA audit concentration and the measured concentration was required prior to analysis of the commercial cylinders. Zero and span checks were performed during the analysis period, according to EPA Traceability Protocol No. 1, to ensure stable instrument performance.

Audit 5 cylinder gases were analyzed during the period March 26-27, 1981. Because of the large number of cylinders (28) to be analyzed and the relatively high flow rate (2 ft^3/h) required by the analyzer, a GMPS was chosen for span checks rather than an NBS-SRM. Cylinders of NO in N_2 prepared by Scott-Marrin, Inc. for Audit 4 were compared with an appropriate SRM and found to have degraded less than the average 1 percent per month specified in EPA Traceability Protocol No. 1. These cylinders were used as the GMPS in Audit 5.

3.2 ANALYSIS OF SULFUR DIOXIDE CYLINDERS

A TECO pulsed fluorescent SO_2 analyzer-Series 40 (S/N SDM-6997-90) was used to analyze the SO_2 cylinder concentrations. The analyzer was calibrated as described in Section 3.1. NBS-SRMs at 972 ppm and 95.1 ppm were used to provide calibration concentrations by dilution. An NBS-SRM at 45.7 ppm was used without dilution to check the calibration curve. After the multipoint calibration, audit cylinders provided by EPA were analyzed. Agreement to within ±3 percent between the EPA audit and the measured concentrations was required prior to analysis of the commercial cylinders. Zero (nitrogen) and span checks were performed during the analysis, according to EPA Traceability Protocol No. 1, to ensure stable instrument performance.

Audit 5 cylinder gases were analyzed during the period April 8-14, 1981 (500 ppm) and June 15, 1981 (90 ppm). The delay in analysis of the 90 ppm cylinders of SO_2 resulted from delays in receiving the 45.7 and 95.1 ppm SRMs from NBS. Because of the large number of cylinders (26) to be analyzed and the relatively high flow rate (3 ft^3/h) required by the analyzer, a GMPS was chosen for span checks instead of an NBS-SRM. Cylinders of SO_2 in N_2 prepared by Airco for Audit 4 were compared with an appropriate SRM and found to have degraded less than the average 1 percent per month specified in EPA Traceability Protocol No. 1. These cylinders were used as the GMPS in Audit 5.

3.3 ANALYSIS OF CARBON MONOXIDE CYLINDERS

A Bendix nondispersive infrared analyzer Model 8501-5CA(S/N BO4574) was used to analyze CO cylinder concentrations. The analyzer was calibrated as described in Section 3.1, using NBS-SRMs to provide calibration concentrations. After the multipoint calibration, an audit cylinder provided by EPA was analyzed. Agreement to within ± 3 percent between the EPA audit and the measured concentrations was required prior to analysis of the commercial cylinders. Zero (nitrogen) and span checks were performed during the analysis, according to EPA Traceability Protocol No. 1, to ensure stable instrument performance.

Audit 5 cylinder gases were analyzed during the period March 18-19, 1981. Because of the large number of cylinders (28) to be analyzed and the relatively high flow rate (3 ft^3/h) required by the analyzer, a GMPS was chosen for span checks rather than an NBS-SRM. Cylinders of CO in N_2 prepared by Airco were compared to an appropriate NBS-SRM and used as the GMPS in Audit 5.

3.4 EPA QUALITY ASSURANCE PROGRAM

To assess the quality of data obtained during the analysis of commercial cylinders, EPA conducted an external quality assurance program consisting of a performance audit of the analyzers used by RTI to determine cylinder concentrations. EPA provided audit cylinders of NO, CO, and SO_2 in nitrogen to RTI for analysis prior to analysis of Audit 5 cylinder gases. RTI analyzed the EPA audit cylinders, determined the concentration based on the calibration curve of the source analyzers, and reported the data to EPA. If the agreement between the audit cylinder and the measured concentration was within ± 3 percent, RTI proceeded to analyze each commercial gas cylinder. If the measured level exceeded the ± 3 percent limit, then recalibration of the source analyzer and reanalysis of additional audit cylinders were required. The data from the EPA performance audit are shown in Table 4. The agreement between the RTI measured concentrations and the EPA audit concentrations was within ± 3 percent for all cylinders.

In addition to the EPA performance audit, EPA performed a confirmation analysis of any cylinder gas where the percent accuracy between the manufacturer's analysis and the mean of RTI's analysis was greater than ± 4 percent. EPA analysis results are included in Tables 5-7, whenever required by the above criterion.

TABLE 4. EPA PERFORMANCE AUDIT OF RTI

Cylinder no.	Pollutant	RTI analysis date	RTI measured conc. (ppm)	EPA audit conc. (ppm)	Difference RTI-EPA (ppm)	Percent accuracy (%)
FF-100554	CO Bal. N_2	March 19, 1981	479	476	3	0.6
JJ1199	CO Bal. N_2	March 16, 1981	44.7	43.9	0.8	1.8
FF6433	NO Bal. N_2	March 25, 1981	444	449	-5	-1.1
LL4679	NO Bal. N_2	March 25, 1981	50.5	50.7	-0.2	-0.4
JJ1045	SO_2 Bal. N_2	April 7, 1981	574	576	-2	-0.3
JJ1514	SO_2 Bal. N_2	June 10, 1981	93.5	93.2	0.3	0.3

Percent accuracy = 100(RTI - EPA)/EPA.

SECTION 4

RESULTS OF CYLINDER GAS ANALYSES

The results for Audit 5 are given in Tables 5 through 7. Each table includes manufacturer, cylinder type, manufacturer's analysis, mean of RTI analysis, EPA-QAD confirmation analysis (if difference between manufacturer and RTI analyses is $\geq \pm 4$ percent), ppm difference, and percent accuracy. Table 5 gives the results for sulfur dioxide, Table 6 for nitric oxide, and Table 7 for carbon monoxide.

Audits 3 and 4 included a reanalysis of cylinder gases from the preceding audit. The purpose of this reanalysis was to judge the stability of the gases since the previous analysis. A reanalysis of cylinder gases obtained and analyzed during Audit 4 was not performed during Audit 5, since stability of these gases had been demonstrated in Audits 3 and 4.

TABLE 5. RESULTS OF SULFUR DIOXIDE CYLINDER ANALYSES (AUDIT 5) - April-June 1981

Manufacturer	Cylinder Construction	Manufacturer's Analysis* (ppm)	Mean of RTI Analysis** (ppm)	EPA-QAD Analysis (ppm)	Difference MFG - RTI (ppm)	Percent Accuracy (%)
AGA Burdox, Inc.	Aluminum	525	495	496	30	6.1
	Aluminum	96.0	88.1	87.9	7.9	9.0
Air Monitoring Gas Company		Company does not supply SO_2				
Airco Industrial Gases	Aluminum	494	487	***	7	1.4
	Aluminum	89.0	87.0	***	2	2.3
Air Products & Chemicals, Inc.	Steel	503	527	524	-24	-4.6
	Steel	88.0	129	129	-41	-31.7
Big Three Industries	Aluminum	546	433	438	113	26.1
	Aluminum	97.0	70.1	70.1	26.9	38.4
Ideal Gas Products	Aluminum	500	447	451	53	11.9
	Aluminum	100	94.3	94.6	5.7	6.0
Liquid Carbonic Corp.	Aluminum	492	510	***	-18	-3.5
	Aluminum	91.6	91.8	***	- 0.2	-0.2
Matheson Gas Products	Steel	503	541	537	-38	-7.0
	Steel	98.0	108	108	-10	-9.3
MG Scientific Gas Products	Aluminum	524	367	367	157	42.8
	Aluminum	86.6	40.8	38.6	45.8	112
North East Cryogenics	Aluminum	500	462	466	38	8.2
	Aluminum	100	89.2	89.1	10.8	12.1
Scientific Gas Products, Inc.	Aluminum	530	499	500	31	6.2
	Aluminum	90.0	80.5	79.5	9.5	11.8
Scott Environmental Tech., Inc.	Aluminum	506	508	***	-2	-0.4
	Aluminum	94.2	91.3	***	2.9	3.2
Scott-Marrin Inc.	Aluminum	485	487	***	-2	-0.4
	Aluminum	84.6	84.4	***	0.2	0.2
Linde Div. of Union Carbide	Steel	490	459	466	31	6.8
	Steel	100	168	171	-68	-40.5

* Manufacturer's certified analysis.

** Mean of three analyses.

*** EPA-QAD confirmation analysis not required.

Percent accuracy = 100(Manufacturer - RTI)/RTI.

TABLE 6. RESULTS OF NITRIC OXIDE CYLINDER ANALYSES (AUDIT 5) - April 1981

Manufacturer	Cylinder Construction	Manufacturer's Analysis* (ppm)	Mean of RTI Analysis** (ppm)	EPA-QAD Analysis (ppm)	Difference MFG - RTI (ppm)	Percent Accuracy (%)
AGA Burdox, Inc.	Aluminum	303	305	***	-2	-0.7
	Aluminum	46.8	48.2	***	-1.4	-2.9
Air Monitoring Gas Company	Steel	297	304	***	-7	-2.3
	Steel	51.5	54.8	53.9	-3.3	-6.0
Airco Industrial Gases	Aluminum	299	296	***	3	1.0
	Aluminum	49.2	50.6	***	-1.4	-2.8
Air Products & Chemicals, Inc.	Steel	294	297	***	-3	-1.0
	Steel	50.0	52.3	***	-2.3	-4.4
Big Three Industries	Aluminum	250	263	***	-13	-4.9
	Aluminum	34.0	36.5	37.1	- 2.5	-6.8
Ideal Gas Products	Aluminum	278	277	***	1	0.4
	Aluminum	45.0	45.5	***	-0.5	-1.1
Liquid Carbonic Corp.	Aluminum	278	284	***	-6	-2.0
	Aluminum	48.0	47.2	***	0.8	1.7
Matheson Gas Products	Steel	295	297	***	-2	-0.7
	Aluminum	45.0	46.4	***	-1.4	-3.0
MG Scientific Gas Products	Aluminum	292	270	276	22	8.1
	Aluminum	57.0	47.5	47.3	9.5	20.0
North East Cryogenics	Aluminum	278	279	***	-1	-0.4
	Aluminum	45.0	44.3	***	0.7	1.6
Scientific Gas Products, Inc.	Aluminum	294	298	***	-4	- 1.3
	Aluminum	41.0	46.3	48.3	-5.3	-11.4
Scott Environmental Tech., Inc.	Aluminum	314	315	***	-1	-0.3
	Aluminum	53.0	53.6	***	-0.6	-1.1
Scott-Marrin, Inc.	Aluminum	294	291	***	3	1.0
	Aluminum	48.7	49.2	***	-0.5	-1.0
Linde Div. of Union Carbide	Steel	315	313	***	2	0.6
	Steel	530****	514	***	16	3.1

* Manufacturer's certified analysis.

Percent Accuracy = 100(Manufacturer - RTI)/RTI.

** Mean of three analyses.

*** EPA-QAD confirmation analysis not required.

****Nominal 50 ppm ordered but 530 ppm shipped.

TABLE 7. RESULTS OF CARBON MONOXIDE CYLINDER ANALYSES (AUDIT 5) - April 1981

Manufacturer	Cylinder Construction	Manufacturer's Analysis* (ppm)	Mean of RTI Analysis** (ppm)	EPA-QAD Analysis (ppm)	Difference MFG - RTI (ppm)	Percent Accuracy (%)
AGA Burdox, Inc.	Aluminum	488	495	***	- 7	-1.4
	Aluminum	50.9	52.1	***	- 1.2	-2.3
Air Monitoring Gas Company	Steel	495	493	***	2	0.4
	Steel	50.0	46.2	46.6	3.8	8.2
Airco Industrial Gases	Aluminum	451	449	***	2	0.4
	Aluminum	47.0	45.2	45.5	1.8	4.0
Air Products & Chemicals, Inc.	Steel	427	491	488	-64	-13.0
	Steel	44.4	52.8	52.9	- 8.4	-15.9
Big Three Industries	Steel	529	532	***	-3	-0.6
	Steel	53	53.0	***	0.0	0.0
Ideal Gas Products	Aluminum	504	489	***	15	3.1
	Aluminum	50.5	50.3	***	0.2	0.4
Liquid Carbonic Corp.	Aluminum	492	489	***	3	0.6
	Aluminum	49.1	49.0	***	0.1	0.2
Matheson Gas Products	Aluminum	507	586	575	-79	-13.5
	Aluminum	56	59.9	61.1	- 3.9	- 6.5
MG Scientific Gas Products	Aluminum	457	453	***	4	0.8
	Aluminum	47.1	50.5	50.7	-3.4	-6.7
North East Cryogenics	Aluminum	501	485	***	16	3.3
	Aluminum	49.3	49.8	***	-0.5	-1.0
Scientific Gas Products, Inc.	Aluminum	500	495	***	5	1.0
	Aluminum	42.0	50.2	50.4	-8.2	-16.3
Scott Environmental Tech., Inc.	Aluminum	505	504	***	1	0.2
	Aluminum	50.0	49.6	***	0.4	0.8
Scott-Marrin, Inc.	Aluminum	496	499	***	-3	-0.6
	Aluminum	51	51.0	***	0.0	0.0
Linde Div. of Union Carbide	Steel	500	484	***	16	3.3
	Steel	50	49.1	***	0.9	1.8

* Manufacturer's certified analysis.

** Mean of three analyses.

*** EPA-QAD confirmation analysis not required.

Percent accuracy = 100(Manufacturer - RTI)/RTI.

SECTION 5

SUMMARY OF RESULTS OF AUDITS 1 THROUGH 5

The results for Audits 1 through 5 of commercial cylinder gases are summarized in Tables 8, 9, and 10. Table 8 gives the results for sulfur dioxide, Table 9 for nitric oxide, and Table 10 for carbon monoxide.

TABLE 8. SUMMARY OF RESULTS FOR AUDITS 1 THROUGH 5 OF COMMERCIAL CYLINDERS FOR SULFUR DIOXIDE

Manufacturer	Cylinder Construction	Nominal Conc. (ppm)	Percent Accuracy Audit 1 (June 78)	Audit 2 (Jan.79)	Audit 3 (Sept.79)	Audit 4 (Apr.80)	Audit 5 (May 81)
AGA Burdox, Inc.	Aluminum	500	*	*	*	*	6.1
	Aluminum	90	*	*	*	*	9.0
Air Monitoring Gas Company	Company does not supply SO_2						
Airco Industrial Gases	Aluminum	500	*	-0.6	-0.8	-1.9	1.4
	Aluminum	90				6.5	2.3
Air Products & Chemicals, Inc.	Steel	500	9.0	2.6	1.0	-0.2	- 4.6
	Steel	90				18.8	-31.7
Big Three Industries	Steel	500	7.5	1.4		-6.1	
	Aluminum	500			-5.5		26.1
	Steel	90				-1.2	
	Aluminum	90					38.4
Ideal Gas Products	Steel	500	4.0	2.9	-8.8		
	Aluminum	500				-21.0	11.9
	Steel	90	-8.0	-35.7	-7.0		
	Aluminum	90				-25.0	6.0
Liquid Carbonic Corp.	Steel	500	2.1				
	Aluminum	500		-0.8	-1.0	4.3	-3.5
	Aluminum	90				-7.5	-0.2
Matheson Gas Products	Steel	500	*	-0.8			-7.0
	Aluminum	500			-0.4	-0.2	
	Aluminum	90				-6.1	
	Steel	90					-9.3
MG Scientific Gas Products	Aluminum	500	-7.2	1.4	-0.8		42.8
	Steel	500				9.1	
	Aluminum	90	-9.4		-3.3		112
	Steel	90				12.2	
North East Cryogenics	Aluminum	500					8.2
	Steel	500	14.7	-12.5			
	Steel	90	-10.1	-15.6			
	Steel	500	- 4.8(1)		- 3.8	-20.0	
	Steel	500	- 1.0(1)				
	Steel	90	-19.7(1)		-21.6	-35.0	
	Aluminum	90					12.1
Scientific Gas Products, Inc.	Steel	500	-2.4		-12.2		
	Aluminum	500		-2.2		-0.8	6.2
	Steel	90			- 3.0		
	Aluminum	90				-9.5	11.8
Scott Environmental Tech., Inc.	Aluminum	500	- 1.6	-0.8	1.7	0.6	-0.4
	Aluminum	90	-11.3	-3.1	3.2	-1.7	3.2
Scott-Marrin, Inc.	Aluminum	500	0.2	-0.6	0.2	-1.0	-0.4
	Aluminum	90				0.4	0.2
Linde Div. of Union Carbide	Steel	500	5.8	-4.6	8.9	3.2	6.8
	Steel	90	2.2	-2.5	-3.8	13.3	-40.5

* Company not included in audit.

1 These cylinders were not part of the first audit but were procured and analyzed after reviewing the results of the first audit.

Percent accuracy = 100(Manufacturer - RTI)/RTI.

TABLE 9. SUMMARY OF RESULTS FOR AUDITS 1 THROUGH 5 OF COMMERCIAL CYLINDERS FOR NITRIC OXIDE

Manufacturer	Cylinder Construction	Nominal Conc. (ppm)	Percent Accuracy Audit 1 (June 78)	Audit 2 (Jan.79)	Audit 3 (Sept.79)	Audit 4 (Apr.80)	Audit 5 (Apr.81)
AGA Burdox	Aluminum	300	*	*	*	*	-0.7
	Aluminum	50	*	*	*	*	-2.9
Air Monitoring Gas Company	Steel	300	*	*	*	*	-2.3
	Steel	50	*	*	*	*	-6.0
Airco Industrial Gases	Aluminum	300	*	2.0	3.5	0	1.0
	Aluminum	50				-0.8	-2.8
Air Products & Chemicals, Inc.	Steel	300	2.2	0.2	5.6	3.4	-1.0
	Steel	50				-2.7	-4.4
Big Three Industries	Steel	300	11.1	-2.0			
	Aluminum	300			-6.3	-2.3	-4.9
	Aluminum	50				-3.3	-6.8
Ideal Gas Products	Steel	300	>100**	11.8	3.1		
	Aluminum	300	>100**			1.3	0.4
	Steel	50	-0.7(1)	-12.9	4.7		
	Aluminum	50	4.0(1)			0.2	-1.1
Liquid Carbonic Corp.	Steel	300	-2.0				
	Aluminum	300		-2.0	-3.4	2.2	-2.0
	Aluminum	50				1.5	1.7
Matheson Gas Products	Steel	300	*	2.2			-0.7
	Aluminum	300			-12.4	2.3	
	Aluminum	50				-1.8	-3.0
MG Scientific Gas Products	Aluminum	300					8.1
	Steel	300	-4.8	-5.2	5.7	10.0	
	Steel	50			22.2	21.4	
	Aluminum	50					20.0
North East Cryogenics	Aluminum	300					-0.4
	Steel	300	>100**	7.6	4.0	4.2	
	Steel	50	>100**	53.8	>100**	7.4	
	Steel	300	-0.7(1)				
	Steel	50	4.0(1)				
	Aluminum	50					1.6
Scientific Gas Products, Inc.	Steel	300	-2.0	-2.8	0		
	Aluminum	300				0	- 1.3
	Steel	50			0		
	Aluminum	50				-0.2	-11.4
Scott Environmental Tech., Inc.	Aluminum	300	0.0	0.3	-1.0	1.1	-0.3
	Aluminum	50	0.2	2.8	-2.8	-3.3	-1.1
Scott-Marrin, Inc.	Aluminum	300	2.3	1.0	- 0.6	0	1.0
	Aluminum	50				- 0.2	- 1.0
Linde Div. of Union Carbide	Steel	300	2.3	3.4	8.3	- 2.8	0.6
	Steel	50	0.8	0.4		- 2.0	
	Steel	500			- 1.6		
	Steel	500***					3.1

* Company not included in audit survey.

** Actual percent accuracy not calculated but was greater then 100%.

*** Nominal 50 ppm ordered but 530 ppm shipped.

(1) These cylinders were not part of the first audit but were procured and analyzed after reviewing the results of the first audit.

Percent accuracy = 100(Manufacturer - RTI)/RTI.

TABLE 10. SUMMARY OF RESULTS FOR AUDITS 1 THROUGH 5 OF COMMERCIAL CYLINDERS FOR CARBON MONOXIDE

Manufacturer	Cylinder Construction	Nominal Conc. (ppm)	Percent Accuracy Audit 1 (June 78)	Audit 2 (Jan.79)	Audit 3 (Sept.79)	Audit 4 (Apr.80)	Audit 5 (Apr.81)
AGA Burdox	Aluminum	500	*	*	*	*	- 1.4
	Aluminum	50	*	*	*	*	- 2.3
Air Monitoring Gas Company	Steel	300	*	*	*	*	0.4
	Steel	50	*	*	*	*	8.2
Airco Industrial Gases	Aluminum	500	*	*	3.3	1.6	0.4
	Aluminum	50				- 0.4	4.0
Air Products & Chemicals, Inc.	Steel	500	*	*	1.9	- 0.5	-13.0
	Steel	50				0.6	-15.9
Big Three Industries	Aluminum	500	*	*	- 3.5		
	Steel	500				1.4	- 0.6
	Steel	50				14.1	0.0
Ideal Gas Products	Aluminum	500	*	*			3.1
	Steel	500			9.2	0.4	
	Steel	50			- 1.2	-14.6	
	Aluminum	50					0.4
Liquid Carbonic Corp.	Aluminum	500	*	*	- 1.1	- 0.2	0.6
	Aluminum	50				- 0.6	0.2
Matheson Gas Products	Aluminum	500	*	*	- 1.1	11.3	-13.5
	Aluminum	50				- 3.3	- 6.5
MG Scientific Gas Products	Aluminum	500	*	*			0.8
	Steel	500			- 7.5	3.3	
	Steel	50			7.9	- 3.5	
	Aluminum	50					- 6.7
North East Cryogenics	Aluminum	500	*	*			3.3
	Steel	500			- 1.5	0.2	
	Steel	50			- 3.9	-12.8	
	Aluminum	50					- 1.0
Scientific Gas Products, Inc.	Steel	500	*	*	2.6		
	Aluminum	500				2.6	1.0
	Steel	50			0.2		
	Aluminum	50				- 2.3	-16.3
Scott Environmental Tech., Inc.	Aluminum	500	*	*	1.2	0.6	0.2
	Aluminum	50			- 3.3	- 1.1	0.8
Scott-Marrin, Inc.	Aluminum	500	*	*	2.8	1.0	- 0.6
	Aluminum	50				- 1.0	0.0
Linde Div. of Union Carbide	Steel	500	*	*	1.6	0.8	3.3
	Steel	50			17.8	6.8	1.8

* Carbon monoxide was not included in Audits 1 and 2.

Percent accuracy = 100(Manufacturer - RT!)/RTI.